which corresponds to the representation described in a problem (Discrete-Time Systems in the Time-Domain (Page 228)) of a length-q boxcar filter.

Solution to Exercise 5.14.4

The unit-sample response's duration is q +1 and the signal's N_x. Thus the statement is correct.

Solution to Exercise 5.15.1

Let N denote the input's total duration. The time-domain implementation requires a total of $N(2q + 1)$ computations, or $2q +1$ computations per input value. In the frequency domain, we split the input into

$$\frac{N}{N_x}$$

sections, each of which requires

$$\left(1+\frac{q}{N_x}\right)\log_2(N_x+q)+7\frac{q}{N_x}+6$$

per input in the section. Because we divide **again** by N_x to find the number of computations per input value in the entire input, this quantity decreases as N_x increases. For the time-domain implementation, it stays constant.

Solution to Exercise 5.15.2

$$\cos(2\pi fn-\phi)=\cos\left(2\pi f\left(n-\frac{\phi}{2\pi f}\right)\right).$$

The delay is not computational delay here the plot shows the first output value is aligned with the filter's first input although in real systems this is an important consideration. Rather, the delay is due to the filter's phase shift: A phase-shifted sinusoid is equivalent to a time-delayed one:

$$\cos(2\pi fn-\phi)=\cos(2\pi f(n-\frac{\phi}{2\pi f}))$$

All filters have phase shifts. This delay could be removed if the filter introduced no phase shift. Such filters do not exist in analog form, but digital ones can be programmed, but not in real time. Doing so would require the output to emerge before the input arrives!

Solution to Exercise 5.16.1

We have $p + q +1$ multiplications and $p + q - 1$ additions. Thus, the total number of arithmetic operations equals $2(p + q)$.